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Design Perspective of Environmental Interventions through the Stroop Effect, Juggling, and Volunteering for Successful Ageing and Cognitive Health: A Review

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Abstract

Environmental design is one of the solutions that supports the idea of successful ageing as well as cognitive health. Designing with environmental interventions offers opportunities for restoration, maintenance, or even enhancement of cognition, particularly in ageing people. Problems of cognitive health, such as mild cognitive impairment and dementia, are frequently and naturally found in ageing people. Design practices and experimental studies in related fields are moving forward at a rapid pace. However, less data are available in relation to design perspectives for cognitive health in the ageing population. This article reviews the benefits of environmental interventions in enhancing cognitive function for ageing people. Relevant English language documents were searched and reviewed through online databases e.g. Scopus, PubMed, Web of Science, Google Scholar and ResearchGate. In this review, the environmental interventions include both physical and social environment interventions. The physical interventions focus on selective attention and decision-making via the Stroop effect and juggling balls respectively. The social intervention focuses on positive behaviour and benefits related to volunteerism and volunteer activities. This article presents environmental interventions that can be integrated as normal daily activities for ageing people to live healthier and more cognitively enriching lives. These interventions could be used in wellness design strategies and applications for designers. The findings of this review also extend the boundaries of designing for the ageing population as an advantage for specialists. Designing with an understanding of cognitive health in ageing people is beneficial and recommended.

Keywords

Environmental design; Physical environment; Social environment; Cognitive ageing; Design for ageing

1. Introduction

Designers are key to contributing solutions for a variety of challenges not only today but also in the future. One of the novel and positive directions in design research is the movement of design thinking into non-traditional fields, including health care services and medical products. Specializations and interventions such as environmental design, inclusive design, ageing design, and cognitive design are growing and have a promising future (Margolin, 2015).

Environmental interventions that include both the physical and social environments have been increasingly used in design to enhance the quality of life (Tiraphat et al., 2017). According to WHO guidelines, physical and social environments are supposed to encourage and promote active ageing by contributing opportunities for health and participation so as to improve the well-being of the ageing population. Physical environment refers to the natural environment and the built (or manmade) environment. Social environment refers to the relationships and society with which the individuals are involved, including social influencers such as friends, family, and close members (Leunga et al., 2018; Tiraphat et al., 2017). The dynamic interplay between physical and social environments can shape our behaviours as well as having an impact on cognition (Cassarinoa & Setti, 2015).

There are lines of evidence that interventions related to physical and social environments can have beneficial effects on maintaining and improving cognitive health in ageing people (Cassarinoa & Setti, 2015; Chanbenjapipu et al., 2023). Previous studies indicated that physical interventions (e.g. Stroop test and juggling balls) are associated with the process of successful ageing (Chuangchai & Siripakarn, 2019; Chuangchai, 2017). When compared to younger people, ageing people can enhance their Stroop performance through regular program participation. (Burger et al., 2020). Besides, ageing people have shown a clear improvement in juggling skills and their results are equivalent to those of younger people (Voelcker-Rehage & Willimczik, 2006). By practising Stroop and juggling balls, the qualities of attention and decision are increased (Chuangchai & Siripakarn, 2019). Also, past studies of social intervention suggested that social engagement, social activity, and social support groups or programs contribute to healthy ageing (Fu et al., 2018; Hajek et al., 2017). However, there is less evidence related to the long-term impact of social intervention on ageing people.

Cognitive function is a comprehensive term that encircles the set of higher-order processes related to acquisition of knowledge, processing of information, and reasoning (Motes et al., 2018). The cognitive function is a series of allied cognitive abilities for reaching goal-directed behaviours (Ingold et al., 2020). Advancing age is closely associated with cognitive decline, including poor attention and decision-making deficit, which results in a decreased processing speed and increased variation of decision-making accuracy (Forstmann et al., 2011). Cognitive impairment is one of the age-related mechanisms that can illustrate the differences in intelligence (Kelly, 2020). Several lines of evidence in cognitive dysfunction have reported how cognitive impairments are still the biggest problem in ageing people e.g. falls, mild cognitive impairment, dementia, depression, and loneliness (Bu et al., 2020; Griffithsa et al., 2020). These are major health challenges that are associated with the exponential ageing of the world's population. Mild cognitive impairment and dementia in ageing people are not only linked to a low quality of life, but also mortality (Chang et al., 2017).

The increasing proportion of the ageing population worldwide is a challenge for designers. Designing with environmental interventions offers opportunities for restoration, maintenance, or even enhancement of cognition, particularly in ageing people. Selective attention through the Stroop test and the decision-making process reflected by juggling balls are introduced as the physical intervention. In addition, volunteering activity as positive behaviour that produces benefits is discussed as an example of social intervention. In this review,

the proposed interventions are linked with essential cognitive health data in ageing people to produce recommendations for designers and related specialists (e.g. industrial designers, designers for universal design, accessibility designers, and ergonomists) as a way forward to help improve cognitive capacity. The paper provides a better understanding of cognitive capability in ageing people, which is particularly important as lifespan increases.

2. Methods

Documents and published studies in scientific databases e.g. Scopus, PubMed, and Web of Science were searched and reviewed. Electronic databases of Google Scholar and ResearchGate also were searched. Keywords for the search included environmental intervention, physical environment, social environment, cognition, attention, decision-making, volunteer, ageing, and related terms. We required papers selected for review to be written in English. Titles and abstracts of the papers were investigated at the first stage. The full documents were then carefully studied to ensure the relation to the areas of this article.

3. Physical environment intervention

Tools, methods, and programs have been designed to improve cognitive health. The physical environment is one of the interventions in design studies and practices. The physical environment is frequently used to reduce the risks for mild cognitive impairment and dementia. Attention and decision-making with respect to physical interventions are linked to cognitive function and performance. Past studies reported that attention and decision-making interventions contribute to cognitive health as well as to successful ageing (Chanbenjapipu et al., 2023; Chuangchai & Siripakarn, 2019; Kelly, 2020).

Attention is the ability to avoid distractions or situations that interfere with decision-making. This ability assigns cognitive resources to process the information in one's focus (Wennberg et al., 2014). Less information can be managed by ageing persons as compared to younger persons due to lower attention capacity with advancing age (Gajewski et al., 2020). Reduced concentration capacity results in the loss of awareness. Generally, concentration can be interrupted by a shared attention to a secondary stimulus or task. Switching concentration between tasks by mistake is a serious situation for ageing people who have a lack of attention. This condition is exacerbated by an unfamiliar environment and is linked to a greater number of injuries and accidents (Lee et al., 2003; Verghese et al., 2002).

The decision-making process is not only related to cognitive function but also learning and practising skills (Horne et al., 2020). With the repetition of daily practice, the decision-making process can be improved (Ball et al., 2002). The decision-making process requires instruction or a sequence of orders, as well as past failures, to store the related information in developing a skill. Training in the decision-making process can improve the performance of dual-tasking and multitasking skills as well as various other tasks that have not been included in training (Voelcker-Rehage, 2008; Voelcker-Rehage & Willimczik, 2006). Slow reaction time and a low rate of accuracy reflect a high load on attention and decision-making respectively. Reaction time and accuracy are even more challenged when additional items and conditions have to be maintained through a time limit, such as the Stroop test and juggling balls.

3.1 Stroop effect

The Stroop test, also known as the colour-word test, is one of the cognitive tests that is extensively used to assess ageing people and in attention studies (Scarpina & Tagini, 2017). The original test had two components, which are congruent and incongruent conditions. The congruent condition refers to a match between word colour and ink colour (e.g. ''RED'' written in red ink colour). The study subject is asked to name the colour word. Conversely, the incongruent condition refers to a mis-match between word colour and ink colour (e.g. ''RED'' written in blue ink colour). Again, the study subject is asked to name the ink colour (Ludwig et al., 2010). A previous study of cognition in ageing people modified the Stroop test by asking the study subjects to name the opposite of both word colour and ink colour and added another item, the colour of the background, to consider (Chuangchai & Siripakarn, 2019). These modifications made the modified Stroop test more complex than the original test, as shown in Figure 1.

The study subject is asked to respond as quickly and accurately as possible. Generally, the answers are slower for the incongruent condition than the congruent condition. Also, the incongruent condition is more likely to have incorrect answers than the congruent condition. These phenomena are called the Stroop effect or the interference effect (Wühr, 2007). The Stroop effect necessitates attention by focusing on the condition to overcome the automatic word-reading tendency (Zurrón et al., 2014). Previous studies of cognition in the ageing indicated that the Stroop test was associated with functions served by the prefrontal areas (Langenecker et al., 2004; Milham et al., 2002). As such, the Stroop effect can be considered an indicator of attention that represents the performance of ageing brains, and in particular, functions of the prefrontal cortex.

Moreover, the Stroop test with a computerised trail has been suggested as being beneficial for ageing people (Davidson et al., 2003). Results from a real-time strategy test offer an exciting experience that motivates ageing people to stick with the practising and training programme. A previous study indicated that ageing people with the Stroop test were able to gain advantages via technological devices e.g. application on a tablet (Chuangchai & Siripakarn, 2019). In terms of the physical intervention, therefore, the Stroop test is suitable to train selective attention amongst ageing people.

3.2 Juggling balls test

The juggling balls test reflects the problem-solving ability of multiple tasks, which creates a circumstance of complex environments (Zago et al., 2017). The juggling balls test challenges participants to hold more information, several different things at once, in the decision-making process, whilst handling that information (Leroy, Thouvarecq, & Gautier, 2008), as shown in Figure 2. The juggling balls task becomes more complex when increasing the number of balls (e.g. 3 balls, 5 balls, and 7 balls) and even more with reverse cascade.

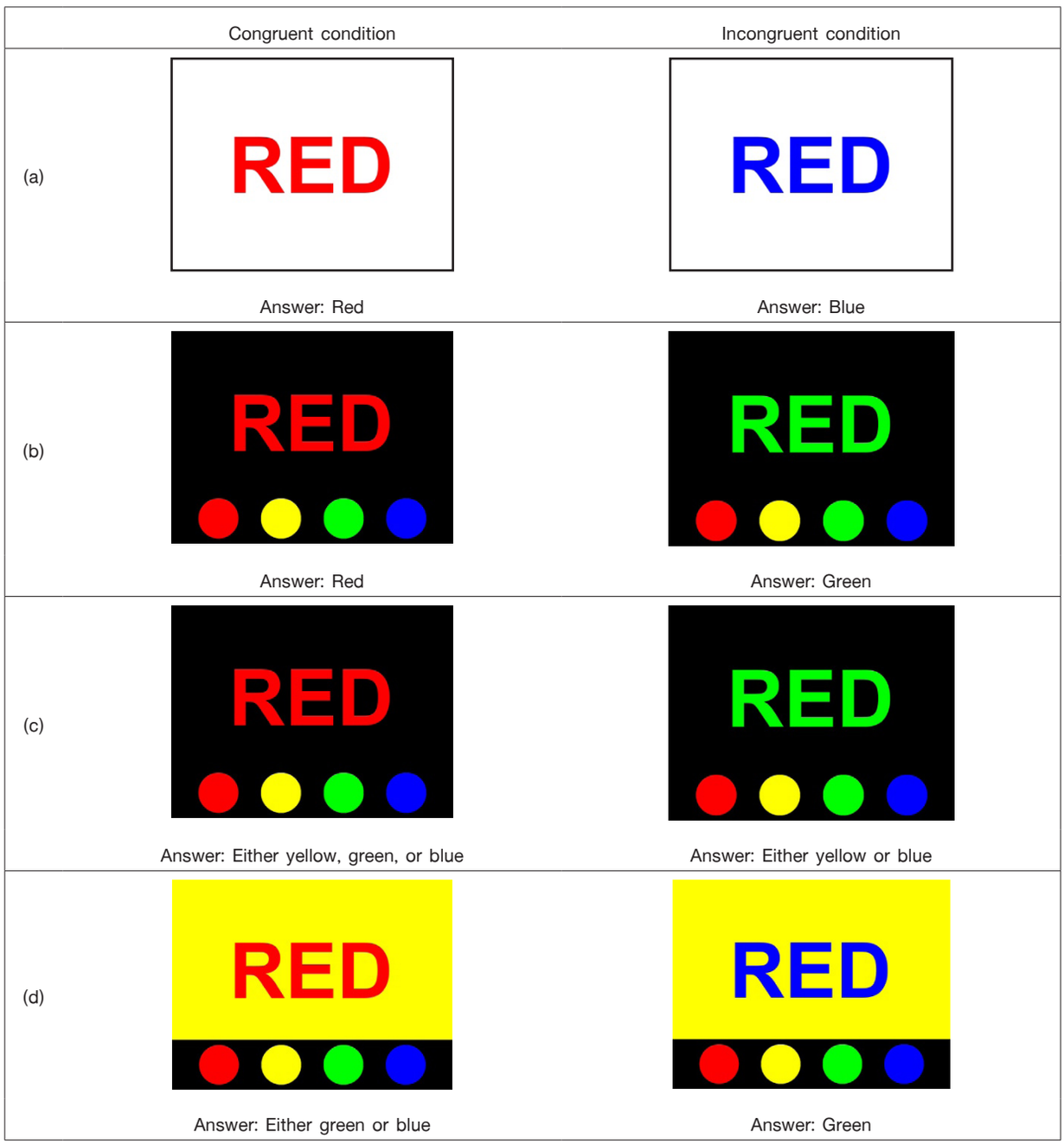

Figure 1 Congruent and incongruent conditions of the Stroop test. (a) Original Stroop test on the white plain paper sheet. (b) Modified Stroop test. (c) Modified Stroop test asking study subjects to name the opposite of both word colour and ink colour. (d) Modified Stroop test with background colour and asking study subjects to name opposite of word colour, ink colour, and background colour. **Note:** Adapted/Translated by permission from (Chuangchai & Siripakarn, 2019).

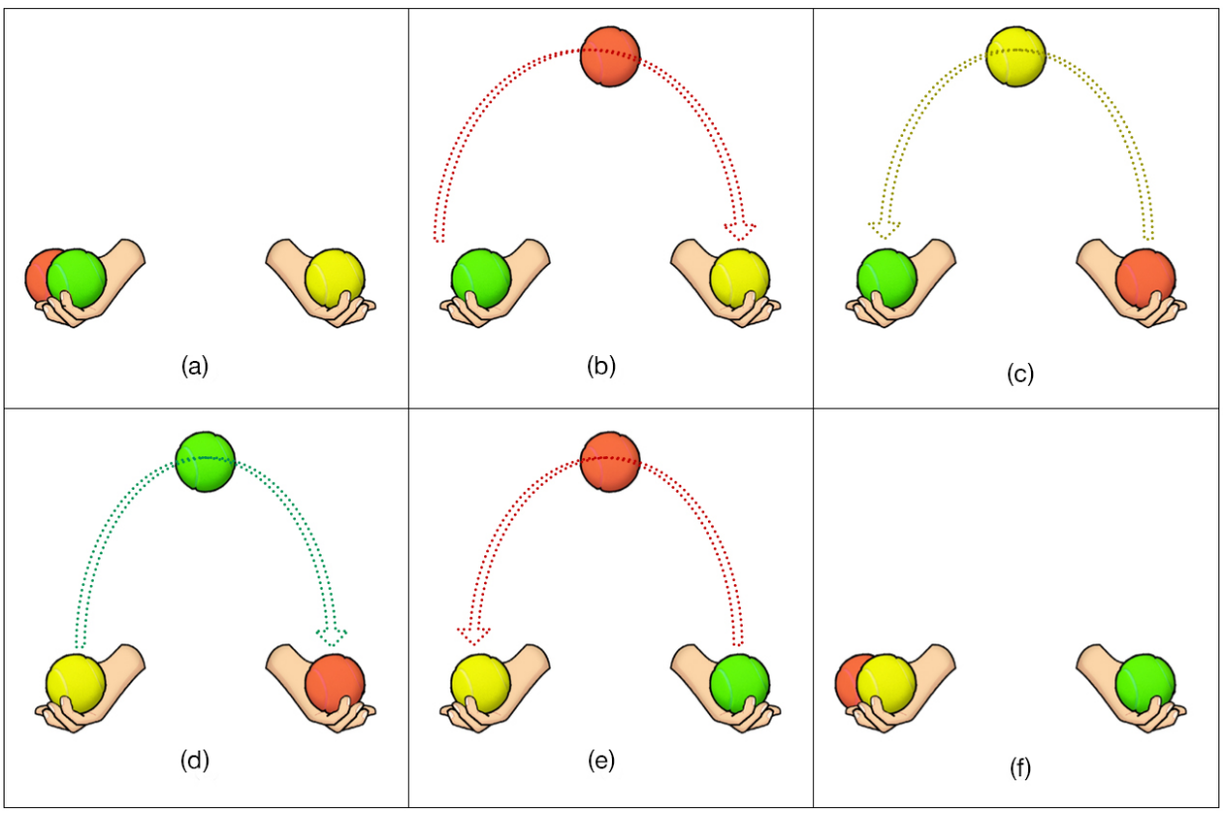

Figure 2 Diagram of juggling with 3 tennis balls. (a) The participants would hold red and green balls with the right hand and a yellow ball in the left hand. (b) Then they have to toss the red ball with the right hand and catch it with the left hand. (c) Before catching the red ball with the left hand, the participants are required to toss the yellow ball with the left hand, and catch it with the right hand. (d) Prior to catching the yellow ball with the right hand, they needed to toss the green ball with the right hand, and catch it with the left hand. (e) Again, before catching the green ball with the right hand, the participants have to toss the red ball with the left hand, (f) and then catch it with the right hand. **Note:** Dotted lines indicate directions of balls. Adapted from (Chuangchai, 2017).

The ball juggling is correlated to motor coordination, which relies on motor function and performance (Haibach et al., 2004). Ageing persons commonly experience a degeneration of motor performance (Chanbenjapipu et al., 2023). Unsurprisingly, ageing persons have slower movement speed and are less smooth in motor performance than younger people since motor performance remains naturally stable throughout young adulthood and diminishes in late adulthood (Boyke et al., 2008; Moustafa, 2014). However, motor learning potential is a capability to achieve certain levels of performance with extended practice (Voelcker-Rehage, 2008), although it should be noted that learning efficiency and proficiency amongst ageing persons does decline. Ageing persons require a much longer time to obtain a performance level compared to young persons (Ren et al., 2013). There are two modes in the training aspect, which are online (improvement during practice) and offline (improvement beyond practice) modes. A past study indicated that young persons experience both online and offline modes of training, while ageing people were limited to the online motor learning mode (Yan et al., 2010).

The ball juggling test is an interesting physical intervention that is complex enough to enhance cognitive function and simple enough to engage and perform in daily life for ageing people. Outstanding performance is positively correlated with the use of eye-hand and eye-foot coordination, sensory-motor function, and complex spatial perception of cognitive abilities (Chanbenjapipu et al., 2023). Thus, a good example of successful ageing is a high level of speed and accuracy in decision-making when a juggler is performing (Mapelli et al., 2012).

4. Social environment intervention

Social engagement and activity have been identified as a lifestyle practice e.g. volunteer activity, which is correlated to maintaining and contributing to cognitive abilities (Fu et al., 2018; Hajek et al., 2017). Volunteer activity has been broadly used as a basis for interventions to prevent cognitive decline for community-dwelling elderly people (Nemoto et al., 2017). Several studies reported that volunteer activity by ageing people affects cognition and determined that social involvement and productive activities lower mortality outcomes as much as physical exercise (Ayalon, 2008; Tan et al., 2006; Varma et al., 2016). In general, ageing with higher social activity was correlated with lower mortality, whilst those with fewer social ties were at increased risk for cognitive decline (Bassuk et al., 1999; Harris & Thoresen, 2005). Specifically, the volunteer activity within a community surrounded by family ties was associated with maintained cognitive function (Choi et al., 2016).

4.1 Volunteer activity as an intervention

The volunteer workforce generally has been characterised as a workforce that is older, mostly retired, and often find their time plentiful with a drive to contribute after a fruitful career (Birdi, 2002). The motivations for volunteerism have been identified as very personal and related to personal interests, careers, or personal previous experiences (due to events involving family members or themselves) (Jones, 1983).

Many volunteers choose to donate their time based on how the activity fits their personal schedule, interests and within their world (Jirovec & Hyduk, 1999). The act of volunteering places an older volunteer in a known or new group of co-workers. Such a group of likeminded colleagues can become a support system providing emotional, mental, or physical support. Working together in a more relaxed and informal setting can be seen as a form of pastime and provides a means of regular supervision ((Intindola et al., 2016; Studer, 2016).

Aside from working with other volunteers, the volunteer manager plays a role in assessing, supporting, and guiding the volunteer (Raymaekers, 2019). This role often extends further to include mental, physical, and emotional support. Volunteer managers can find themselves giving references (for houses, passports, and the like), visiting ill or injured volunteers, and even guiding volunteers to seek appropriate help where needed. This equally applies to protecting the individual volunteers from each other and acting like a social worker. Examples of this include where volunteers are depressed or suicidal and the volunteer manager is required to intervene. These interventions by the volunteer manager can be effectively used as an informal form of social intervention in the life of ageing volunteers. Their role as a trusted third party can provide an ideal opportunity for volunteers to have a structured outlet for issues (Intindola et al., 2016; Studer, 2016). Such an outlet will benefit the ageing population and at times present opportunities for improvement or redirection towards appropriate channels.

4.2 Benefits of volunteering as a social intervention

The vital premise within volunteer management states that the benefits and remuneration of volunteers is distinctly different to paid employees. Rather than largely for financial gain, volunteers engage for a variety of different reasons with a variety of benefits. Volunteers have a limited number of tangible benefits (like food, drinks, or discounts), with the majority of their benefits being intangible or otherwise valuable. People often volunteer for the tangible or immediate intangible motivations and benefits that they value most. Volunteers are not always consciously aware of these intangible benefits though may experience them nonetheless (Gil- Lacruz et al., 2019; Morrow-Howell et al., 2003).

The ageing and older volunteer population consciously identifies companionship and friendship as the most prominent benefit of volunteerism (Smith et al., 2010). These benefits for volunteers extend into social and even medical benefits which result from periods of sustained volunteering activity (Filges et al., 2020).

As a result, volunteering as an intervention that creates networking opportunities and allows volunteers to engage with new environments. These increased social interactions help in reducing loneliness and isolation amongst ageing people (Lee, 2021; Toepoel, 2013). Moreover, the positive act of volunteering provides unconscious health benefits for ageing volunteers. This positive behaviour leads to lower rates of anxiety and depression as well as higher self-esteem and empathy, and including a higher chance of longevity (Bonsdorff & Rantanen, 2011; Lum & Lightfoot, 2005).

Thus, the act of volunteering can provide a form of social intervention, albeit informal and subconscious, that improves the life of the ageing volunteer. As the impacts range from improved cognitive function, lessened anxiety and loneliness and a wider social circle, the support gained from the (perhaps newfound) social environment has great potential for positive impact.

5. Recommendations and future directions

Successful ageing and cognitive health can benefit from environmental interventions. Overall, physical design for ageing people, as indicated by the Stroop effect and juggling balls, is suggested to match their abilities and preferences. On the other hand, the physical design should provide an opportunity that is complex enough to improve their knowledge and increase body movements. Design for adaptive technology and assistive devices (e.g. smartphone, smart glasses or virtual reality glasses, and smartwatch) can bring more plasticity and elasticity to cognitive health in the areas of user interface and user experience design for an application, graphic design, colour in design, typography design, or lighting and colour lighting design. Opportunities in technology design for the built environment and instrumented space e.g. smart living room and smart screen, respectively, also exist (Lindenberger & Mayr, 2014). As mentioned above, there are places where the Stroop effect and design components can be combined to create or add a short period of conditions for practicing the activities of daily living. Furthermore, volume and space design should be prepared to accommodate a range of motion activities and soft exercise e.g. juggling balls. Such design could be planned as home-based or community-based physical activities through ageing-friendly environments. Designers and architects should pay more attention to behavioural design as well as inclusive design since design and planning for accessibility assist ageing people in breaking away from sedentary lifestyles and becoming more social e.g. through volunteering activity. This illustrates the positive association between behavioural design and social intervention through environmental support (Błaszczyk et al., 2020).

This article supports the concept of environmental design that can contribute to successful ageing by shaping cognition. It also highlights some of the intervention studies in both physical and social environments that help to inspire designers in contributing cognitive health applications. Interestingly, a review recently indicated that cognitive function in ageing people was strongly associated with motor function. Together, a combined process between cognitive (referring to a system) and motor (referring to a mechanism) functions was operated as an executive function, which was involved with the built environment through architectural design by creating safe surroundings that enhanced the quality of the elderly's lives. (Chanbenjapipu et al., 2023). Additionally, inner feelings such as happiness and satisfaction with overall health and life are important in successful ageing (Estebsari et al., 2020). However, there are several questions that need to be addressed

by future studies on the association between design in the lived environment and cognitive ageing. An interesting issue for design practices is sensory stimulation for cognitive enhancement in ageing people. Surface textures, finishes, and materials (e.g. flooring design, stepping design, railing design, or handle design) are potential areas of tactile sensation study that could help to alleviate cognitive impairments in ageing people. Additionally, future studies might consider underlying related physiological mechanisms, such as pulse pressure, heart rate variability, and autonomic nervous system in relation to design and cognition of ageing people (Dalise et al., 2020; Grässler et al., 2020). Further work could be conducted on the Stroop application such as the colour contrast ratio and typography design. The relationship between ageing and reverse cascade juggling, e.g. 3 balls and 5 balls, still requires an evaluation in appropriate experimental studies. Furthermore, it is advisable to investigate the impact of other social interactions and engagements on cognition in ageing people. Further studies are needed to determine the longer-term effects of the interventions on the ageing population as well as their cost-effectiveness and impact on socially disadvantaged neighbourhoods. Creative relations of intervention design are an important starting point in enhancing the physical and social environments where ageing people live, in order to improve cognitive health and wellbeing.

6. Conclusions

This article proposes physical and social environmental interventions in promoting and/or maintaining abilities of cognitive health in ageing people. Attention and decision-making can be improved by physical intervention with the Stroop effect and juggling balls. Besides, the benefits of volunteering are discussed as a means for ageing people to increase their openness to novel behaviours as well as decrease isolation and loneliness through social intervention. A deeper understanding of related cognitive mechanisms has brought better insights into the causes of cognitive impairments and a combination of interventions may be key to enhancing cognitive health for the ageing people. This enhanced knowledge of value information could support adaptation of ideas that increase the ability to age successfully. It may contribute in the near future to minimize the likelihood of various health problems and disabilities in the aging population. It also may enhance and increase their quality of life over a long period of time.

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Author contributions

Conceptualization, writing - original draft, and writing - review & editing, W.C.; and visualization and writing - review & editing, S.R. These authors contributed equally to this work. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest

The authors declare no conflict of interest.

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